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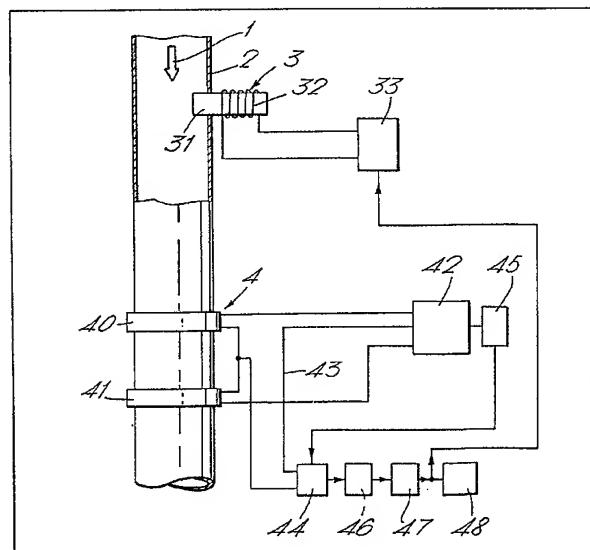
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## (54) Detecting particles in flowing fluids

(57) Apparatus for detecting passage of ferromagnetic particles along an oil-flow line (2) of an engine has a particle sensor (4) provided by two inductive coils (40, 41) spaced apart from one another along the flow-line. Passage of a particle through the coils (40, 41) changes their inductances, this change being used to count the number of particles. Small particles, that would not otherwise be detected

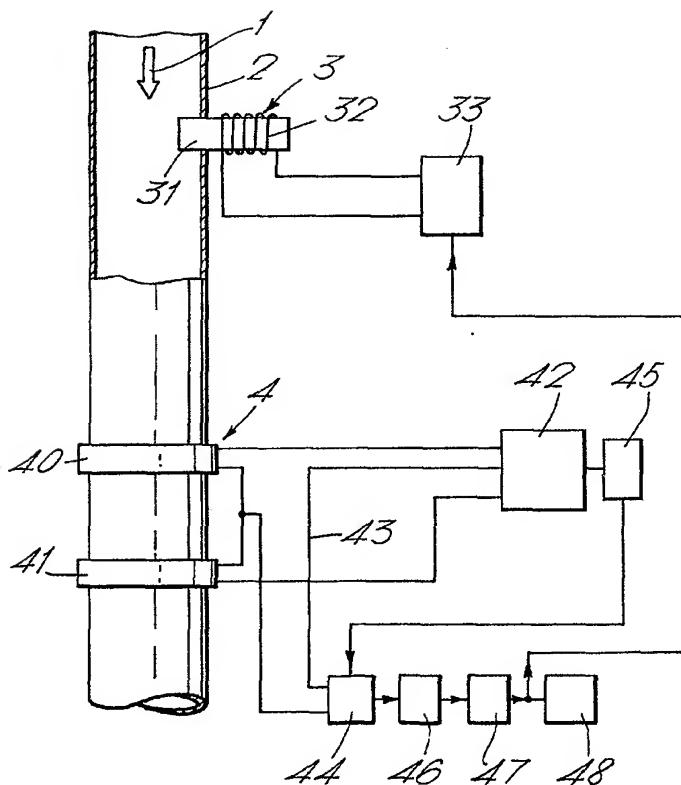
by the sensor (4), are collected upstream of the sensor by an electromagnet (3) that projects within the oil flow-line. When the output of the sensor (4) indicates that a measurable quantity of particles may have been collected by the electromagnet, energisation is terminated and the particles released, as a batch, to the sensor so as to provide a count. Alternatively the particles may be released after predetermined intervals, or in response to a predetermined inductance of the magnet coil (32).



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**SPECIFICATION**  
**Particle detector apparatus**

This invention relates to particle detector apparatus.

5 The invention is concerned in particular with apparatus for the detection of particles in their passage along a defined pathway. In this respect, the invention is especially, though not exclusively, concerned with the detection of metal chips or  
10 other particles, in an oil- or fuel-flow line of an engine.

Knowledge of the nature and rate of occurrence of particles in the oil-flow line of an engine provides a useful check on the health of the  
15 engine, since it is possible by this to anticipate bearing failure or other defects that warrant attention, before these defects have serious consequences.

It is known to insert magnetized plugs in the  
20 oil-flow line of an engine, and to check the accumulation of particles on these at regular intervals of engine operation. Comparison of the extent of particle accumulation with data derived empirically allows a judgement to be made of the engine health. The removal and study of the plugs is time-consuming and tedious, and moreover does not give any indication of the presence of non-ferromagnetic particles. To overcome these disadvantages, particle detector apparatus which  
25 rely on change in inductance of a sensor have been used, such as described, for example, in UK patent specification No. 1 348 881. In such apparatus, a coil is wound around the pathway, passage of an electrically-conductive particle  
30 through the coil causing its impedance to change by virtue of the eddy-current losses produced. One problem with such apparatus, however, is that they may not respond to particles below a certain size, which particles may nevertheless, taken over  
35 a period of time, be indicative of significant wear or damage to the bearings.

It is an object of the present invention to provide particle detector apparatus that may be used substantially to overcome the above-  
40 mentioned problems.

According to one aspect of the present invention there is provided particle detector apparatus including particle sensor means located at a point along a flow-pathway, and accumulator  
50 means located at another point along the flow-pathway upstream of said particle sensor means, said accumulator means being arranged to collect some at least of any particles flowing along the flow-pathway and periodically to release the  
55 collected particles to the sensor means.

In this way, small particles which might not be detected individually by the sensing means, can be passed to the sensor means in a batch large enough for the sensor means to detect and cause  
60 a response.

The accumulator means may be arranged to release the collected particles either in response to the output of the sensor means or after predetermined time intervals.

65 The accumulator means may include magnet means arranged to collect magnetic particles and in this respect, the magnet means may be an electromagnet, the particles being released by ceasing energisation of the electromagnet.

70 According to another aspect of the present invention there is provided a method of detecting particles in their passage along a flow-pathway including the step of collecting some at least of said particles and periodically releasing them as a  
75 batch to particle sensor means, such that the particle sensor means responds to the passage of the batch of particles.

Particle detector apparatus in accordance with the present invention, will now be described, by  
80 way of example, with reference to the accompanying drawing which shows the apparatus schematically in conjunction with an oil-flow system of the engine.

The particle detection apparatus to be  
85 described is for use in the detection of metal chips or other particles occurring in oil flow along an oil-return line of the lubricating system of a gas-turbine engine. The same apparatus is equally applicable to the detection and counting of such particles occurring in the fuel system of the engine.

Oil flows in the direction of the arrow 1 along the oil flow line 2, that is, downwardly of the drawing. The particle detection apparatus has a  
90 particle accumulator 3 mounted in the line 2 upstream from a particle sensing unit 4, the accumulator collecting particles over a period of time and then releasing them for sensing by the unit 4.

100 The particle accumulator 3 is in the form of an electromagnet 30 having a soft-iron pole piece 31 that projects within the oil flow line 2. A coil 32 is wound around that portion of the pole piece 31 outside the oil flow line 2 and its energisation is controlled by an energising unit 33.

The sensing unit 4, mounted downstream from the accumulator 3 includes two identical screened coils 40 and 41 which are wound around the flow line 2 at positions spaced apart along its length.

110 The two coils 40 and 41 are connected in series with an oscillator 42 which supplies an alternating voltage at a frequency of about 100 kHz across them, balanced about earth. The oscillator 42 also provides a reference signal, such as, for example,  
115 an earth reference, on line 43 which is supplied to a demodulator 44 together with an output signal from the junction between the two sensor coils 40 and 41. A phase shift and synchronising unit 45, coupled to the oscillator 42, is connected to the  
120 demodulator 44 and acts to control the phase at which the alternating signals supplied to it are demodulated. The output of the demodulator 44 is connected to a bandpass filter unit 46, the output of the filter unit being connected to a pulse-level  
125 detector 47. The detector 47 functions to select only those signals having an amplitude above a predetermined level, which signals are passed to a counter 48 and to the accumulator energising unit 33.

- The oil flowing in the line may contain many different forms of discontinuity, such as, ferromagnetic particles, non-ferromagnetic metal particles, non-metallic particles, water droplets, air bubbles and so on. In operation, ferromagnetic particles will be attracted towards the pole piece 31 of the accumulator 3 and some of these particles will collect on the pole piece. The lower momentum of the smaller particles means that there will be a greater tendency for these to be collected by the accumulator 3 whilst the larger particles will continue to flow downstream to the sensing unit 4.
- As a discontinuity passes through that portion of the flow line 2 embraced by the upstream coil 40 it causes a change in inductance of the coil and a consequent unbalancing of the circuit formed by the two coils 40 and 41 with the oscillator 42. This produces a burst of modulation of the alternating voltage signal across the input of the demodulator 44, which is closely followed by another signal burst as the discontinuity passes through that portion of the flow-line 2 embraced by the downstream coil 41.
- The phase and magnitude of the signals supplied to the demodulator 44 will vary according to the resistivity permeability, size and shape of the discontinuity passing along the flow line, and will also vary according to the frequency of the oscillator. In the present application the apparatus is for use in providing an indication of engine life and this is most effectively done by measuring the amount of small ferromagnetic debris in the lubricating oil. The apparatus is therefore arranged to count selectively ferromagnetic particles and ignore other discontinuities such as caused by, for example, gas bubbles or carbon particles. To this end, the demodulator 44 is controlled by the unit 45, which is adjusted in this case to provide a maximum signal-to-noise ratio for those input signals approximately twenty degrees out of phase with respect to the alternating signal from the oscillator 33. At the frequency of operation specified of the oscillator 33 the maximum signal-to-noise ratio is produced by passage of ferromagnetic particles whilst, for example, non-ferromagnetic particles will produce signals which are ninety degrees out of phase with ferromagnetic signals and which are therefore heavily attenuated by the demodulator 44.
- In the accumulator 3, the electromagnet 30 is maintained energised so as to collect particles until they are in a sufficient quantity to be detected by the sensing unit 4, it is then deenergised so that the collected particles are swept off as a batch by the liquid in the flow line 2. The coil 32 of the electromagnet 30 may be energised for a predetermined time or, as shown in the drawing, it may be controlled in response to the quantity of particles detected. In this arrangement, the electromagnet 30 remains energised until the quantity of particles that escape being collected by the accumulator are such as to indicate that the quantity of particles

that are collected should be sufficient for detection by the sensing unit 4. Alternatively, the energisation of the electromagnet may be controlled in response to the change in inductance of the pole piece 31, since this will vary as particles come into contact with it.

The pole piece 31 could be covered by a non-magnetic sleeve so that particles can more easily be removed from the pole piece when energisation is removed from the electromagnet 30.

The accumulator need not project within the flow line 2, and, in this respect could be of a form extending around the flow line.

The accumulator 3 need not necessarily be of a magnetic kind. Alternatively, for example, particles could be collected in a similar way by electrostatic means. This would be especially useful for detecting particles in gas-flow lines. In a further embodiment, particles could be collected in a sieve that is periodically rotated so that particles accumulated on one face are blown off into the fluid stream. The particle sensing means need not be of the inductive kind and, in this respect, for example, capacitive or optical systems could be used.

Similar particle detector apparatus could be used in applications other than engines, such as, for example, in chemical or mineral processing plants, fluid heating supply systems, sewage treatment plants, and in open waterways such as rivers and canals.

#### CLAIMS

1. Particle detector apparatus including particle sensor means located at a point along a flow-pathway, and accumulator means located at another point along the flow-pathway upstream of said particle sensor means, said accumulator means being arranged to collect some at least of any particles flowing along the flow-pathway and periodically to release the collected particles to the sensor means.
2. Particle detector apparatus according to Claim 1, wherein said accumulator means is arranged to release the collected particles in response to the output of the sensor means.
3. Particle detector apparatus according to Claim 1, wherein said accumulator means is arranged to release the collected particles after predetermined time intervals.
4. Particle detector apparatus according to any one of the preceding claims, wherein said particle sensor means is arranged to respond to electrically-conductive particles.
5. Particle detector apparatus according to any one of the preceding claims, wherein said particle sensor means includes inductive sensor means.
6. Particle detector apparatus according to Claim 5, wherein the particle sensor means includes two inductive coils spaced apart from one another along the flow-pathway.
7. Particle detector apparatus according to any one of the preceding claims, wherein said accumulator means is arranged to collect

- preferentially particles smaller than a size that would be detected individually by said sensor means.
8. Particle detector apparatus according to any one of the preceding claims, wherein said accumulator means includes magnet means arranged to collect magnetic particles.
9. Particle detector apparatus according to Claim 8, wherein said magnet means is an electromagnet, and wherein particles are released by ceasing energisation of the electromagnet.
10. Particle detector apparatus according to any one of the preceding claims, wherein said accumulator means projects within said flow-pathway.
11. Particle detector apparatus according to any one of the preceding claims, wherein the flow-pathway is an oil-flow line.
12. Particle detector apparatus substantially as hereinbefore described with reference to the accompanying drawing.
13. Fluid-flow system including particle detector apparatus according to any one of the preceding claims.
14. An engine including particle detector apparatus according to any one of Claims 1 to 12.
15. A method of detecting particles in their passage along a flow-pathway including the step of collecting some at least of said particles and periodically releasing them as a batch to particle sensor means, such that the particle sensor means responds to the passage of the batch of particles.
16. A method substantially as hereinbefore described with reference to the accompanying drawing.

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